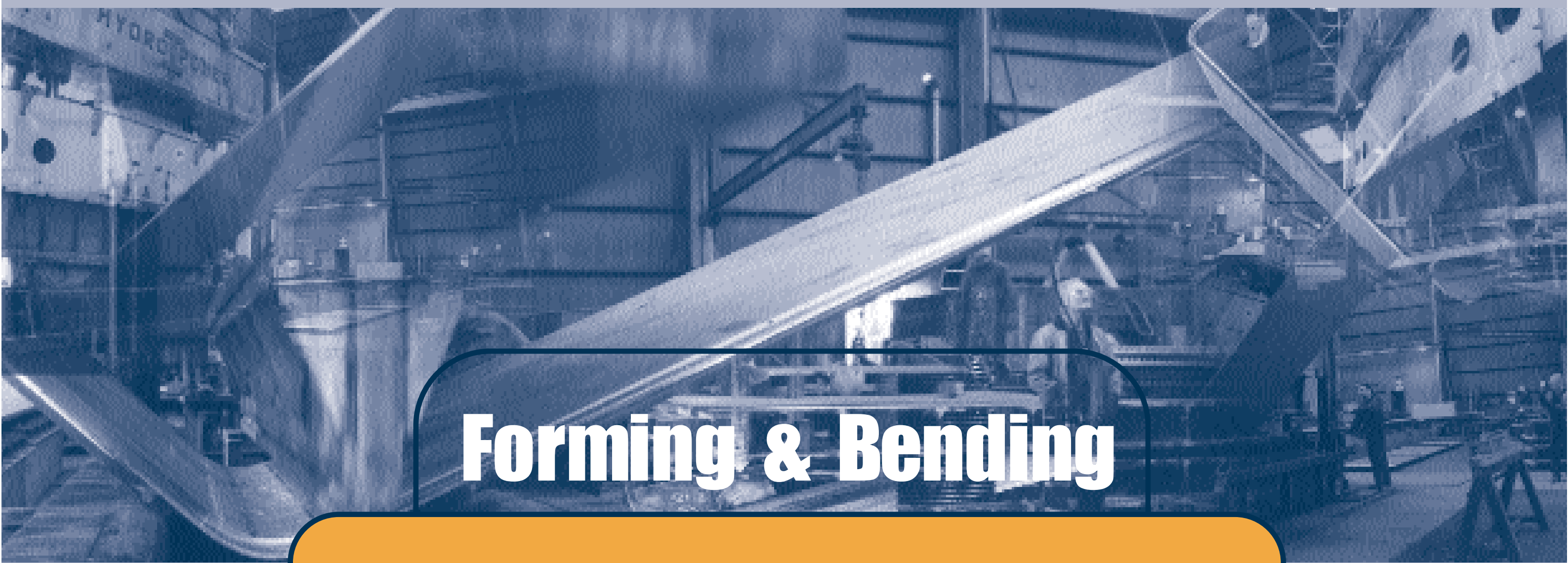
Forming &



Forming & Bending

Useful Fabrication Information

Bending

Introduction

Many plate applications require that the steel be formed to varying extents ranging from simple cold bending in a press brake to deep drawing in complex, multi-stage die presses. The latter is a specialist process outside the scope of this note, however, the metallurgical principles involved and some general guidelines appropriate to the more conventional forming operations are outlined.

The chemical composition, mechanical properties, metallurgical microstructure, surface condition, thickness, edge condition, and forming direction in relation to the rolling direction of the steel, will have an influence on the plate forming properties.

Cold Forming

Cold Forming involves plastic deformation, or stretching, of the material surface on the outside of the bend. The extent to which this plastic deformation can take place without exceeding the limits of the material ductility, controls the minimum radius of bend which can be utilised for a particular application.

The plastic deformation associated with cold forming results in strain hardening of the material and this in turn affects the mechanical properties. In the areas subject to this plastic deformation, ductility and fracture toughness decrease. For certain critical applications it may be necessary either to restrict the radius of the bend to minimise these effects, or even to undertake subsequent heat treatment to restore the original properties.

The major factors affecting the extent to which forming is possible without failure are:

1. Steel type

Low strength steels are generally more ductile than higher strength steels and are therefore capable of being shaped to more restrictive forming radii. Material produced to AS/NZS 3678 and AS/NZS 1594 by BlueScope Steel are fully killed steels with good homogeneity and microstructural cleanness which imparts good formability. Product data sheets give information on minimum bend radii. Generally low carbon content is a prerequisite to good formability and higher carbon steels have limitations in this respect.

2. Direction of Forming Relative to the Principal Rolling Direction of the Plate

The properties of steel plates are, directionally dependant by virtue of the rolling process during manufacture, which elongates the metallurgical structure, inclusions, etc parallel with the principal rolling direction (ie. length direction) of the plates.

Plates (and indeed all steel products), will therefore exhibit different mechanical and physical properties depending on the orientation relative to the original rolling direction. The extent of this directionality dependence of properties varies with steel type, steel mill rolling practice and product size and shape, but the most favourable forming properties will generally be obtained in the longitudinal, or principal steel mill rolling direction. Ductility of steel plates follows this rule and for this reason plates are more readily formed, or stretched, with the bend axis transverse to the principal rolling direction of the plate. Because of reduced ductility, bending with the axis parallel to the principal rolling direction of the plate will normally necessitate larger bend radii.

For recommended cold bending radii on individual grades refer to BlueScope Steel Product data sheets for the grades.

3. Edge and Surface Condition

Steel ductility can be reduced significantly by the presence of local stress raising influences. For this reason the removal of sharp corners on sheared edges, gouge marks on flame cut edges and other similar stress - concentrating sources on either the edge or the surface, should precede cold forming. Attention to the "outside" or tension side of the edge or surface is most important in this respect, particularly in thicker plate where it is necessary to utilise restrictive bend radii. For such applications, careful examination of the edge and surface prior to bending is advised.

Grinding or similar methods should be employed to remove gouge marks, notches, heavy scoring, and sharp edges. Similarly, the localised edge hardening associated with shear cut edges and flame cutting, may impair the cold bending performance of the plates. For particularly critical applications it may be necessary to apply some form of edge conditioning to remove partially the metallurgically affected edge area.

Smoothing of edges and removal of sheared edge arris is recommended.

Where forming is to be carried out without prior removal of the sheared edge arris, positioning of the component with the arris on the inside, or compression side of the bend will reduce the risk of failure during forming.

4. Other Practical Factors

Forming dies should exhibit chamfered corners and openings. The provision of liberal die radii, consistent with the finished component, will minimise excessive local strains and thereby reduce the risk of forming failure.

The risk of failure on forming heavy plate thicknesses or particularly restrictive bends may be somewhat reduced by preheating the plate (to about 75°C) prior to bending. This is particularly applicable to plate thickness above 20mm where the outer fibres of the tension face of the plate are subject to triaxial stress states by virtue of the bulk surrounding material. Brittle failure can result from such conditions and mild heating of the plate will reduce the tendency to failure. For similar reasons, forming should not be undertaken where the plate temperature is below 15°C. Formed plate components will generally exhibit springback on removal of the die or bending press force. This springback is due to the release of elastic strain energy and the magnitude of this strain is directly related to the yield strength of the material. For this reason a slightly greater "overbending" allowance should be made for high yield strength steels.

Recommended Minimum Internal Radius of Cold Bends in Forming

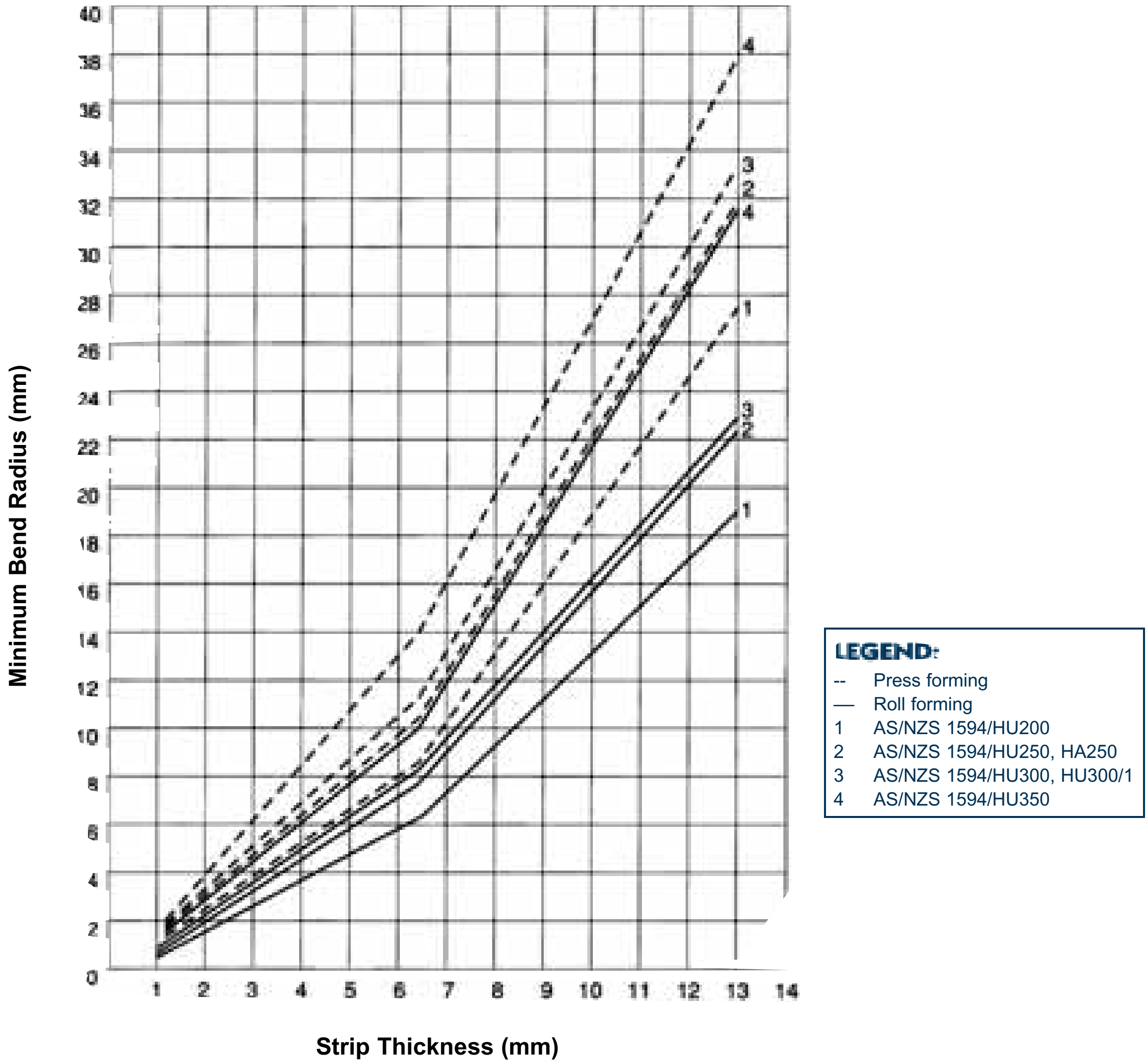


Table1
Recommended Minimum Inside Radius for Cold Bending of Plate Grades During Fabrication (1)

Thickness, T, mm		Bend Direction	AS 3678-200	250	350	WR 350/1
>	≤	(2,3)	AS 1548	7/460	5/490	–
–	6	Transverse Longitudinal	0.5T 1.0T	1.0T 1.5T	2.0T 3.0T	2.0T 3.0T
6	12	Transverse Longitudinal	1.0T 1.5T	1.0T 1.5T	2.0T 3.0T	2.0T 3.0T
12	20	Transverse Longitudinal		1.0T 1.5T	2.5T 3.75T	3.0T 4.5T
20	50	Transverse Longitudinal		4.0T 6.0T	Hot Form Hot Form	
50	–	Both		Hot Form	Hot Form (4)	

Notes:
1. The recommended minimum bending radii of floorplate are as above except where the raised pattern is in tension, when a more liberal radii should be used.
2. A transverse bend is one where the axis of the bend is at right angles to the direction of rolling
3. A longitudinal bend is one where the axis of the bend is parallel to the direction of rolling.
4. Hot forming - refer comments under "Hot Forming."

Properties of Cold Formed Components

For most structural applications, the extent of strain hardening and consequent increase in strength with reduction in toughness and ductility resulting from cold working, need not warrant specific attention. For certain more critical applications however, or where particular processing is to be carried out subsequent to cold forming, it may be necessary to adopt alternative procedures. On most hot rolled plates mechanical properties can be restored by a normalising heat treatment, typically at 900°C, followed by air cooling. This treatment eliminates all traces of cold work. However, such a "cold form-normalize" cycle may not be appropriate to controlled rolled steels which rely on steel mill rolling practice to attain their mechanical properties. Heat treatment of such steels (especially microalloyed steels) may significantly lower the mechanical properties and should not be undertaken except with specialist advice.

Partial restoration of properties and reduction of the residual stresses inherently associated with cold forming may be obtained with a stress relief heat treatment, typically at 600°C.

Pressure vessels, heat exchangers and boilers, including those utilising steel plates to AS1548, are generally subject to specification, or statutory authority requirements in respect of heat treatment after cold forming and hot forming. Reference to the appropriate specification (AS 1210) or authority is recommended before such processing of these steels.

Strain ageing is a metallurgical phenomenon whereby a delayed increase in strength, and loss of ductility and toughness occurs in susceptible steels as a result of strains induced by cold working. The ageing changes are both time and temperature dependent, and proceed very slowly at ambient temperatures. Exposure of a severely cold worked steel plate to elevated temperatures (up to about 450°C) may, however, result in an unacceptable loss of ductility, and may require that the component be subjected to additional heat treatment to restore acceptable mechanical properties. The extent to which strain ageing occurs depends on a large number of factors including steel type, thickness, degree of cold work, etc. Welding of plate material adjacent to areas which have been severely cold worked may result in the area undergoing a thermal cycle sufficient to result in a reduction of toughness and ductility due to the mechanism of strain ageing. Welds on or immediately adjacent to cold worked regions of plate should be avoided if possible for this reason.

The combined effects of hydrogen embrittlement during acid pickling, and strain ageing due to the thermal effects of hot dip galvanising, may result in unacceptably low ductility of cold worked and galvanised components.

Stress relieving, or preferably normalising is recommended prior to galvanising of cold worked components which are to be subjected to any significant degree of stress in service. Brittle failure at quite low stresses can occur if this precaution is not observed, particularly where cold bending is carried out using a sharp edged former.

Hot Forming

Hot forming refers to deformation carried out at a temperature (usually near 900°C) such that the strain hardening and the distorted grain structure produced by the process are rapidly eliminated by the formation of new strain free grains via a mechanism known as recrystallisation. Very large deformations are possible in hot working because the recovery processes keep pace with the deformation. Therefore a much greater degree of forming may be carried out with hot working than with cold working. Additionally, because the strength of steel decreases with increasing temperature, the total energy (or press capability) necessary to deform a given component will be much lower for hot working than for cold working. Hot forming is therefore appropriate to plate applications where the required deformation is greater than that attainable with cold forming (eg. certain pressure vessel heads). Hot forming may also be a desirable alternative to cold forming where press capacity is limited.

There are, however, certain limitations to hot forming. The high temperatures involved often mean that surface oxidation (or scaling) and surface decarburisation may be a problem. It may also be difficult to avoid rolling or pressing into the plate surface, the scale produced during the hot forming operation. Due allowance must be made for thermal expansion and contraction in hot forming.

Certain steel plate grades rely on controlled thermo-mechanical processing at the steelworks in order to establish their mechanical properties. These include AS/NZS 3678-350, WR 350 and impact tested grades (where plates are tested in the as-rolled condition). Such grades have their mechanical properties modified markedly by heat treatment or hot forming above 600°C and are therefore not readily amenable to such processing without specialist guidance.

As a general rule plates should not be soaked for prolonged periods above 950°C, and it is preferable to hot form within normalising range near 900°C.

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BLUESCOPE STEEL
1800 800 789
A.B.N. 19 000 019 625